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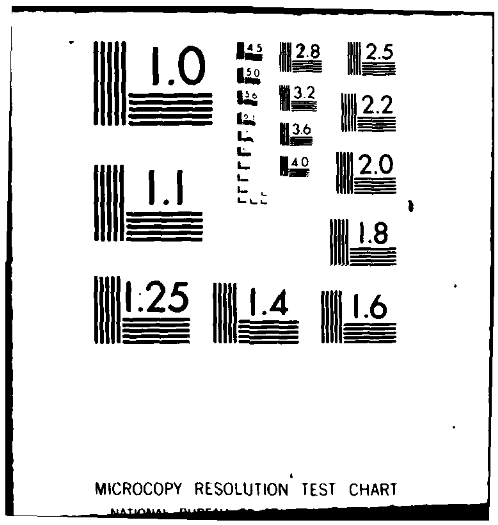
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Modeling Visibility for Locations in Germany Where No Records Exist

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Using a Weibull model for the probability that visibility will be less than a specified distance, regression equations for the two parameters α and β are developed for West Germany which are functions of geographical and climatological variables. Using these equations in a Weibull model enables us to estimate visibility probabilities for stations with no historical data but for which we are willing to assume values for the climatological and geographical variables used in the equations. (continued on next page)

alpha Beta

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Separate models are also developed which, for a specified month and time of day, are valid for the entire region and do not require the values for any other variables.

ACKNOWLEDGEMENT

Special mention must be given to three students who made major contributions to the work in this study. Mark Heuser wrote the general non-linear regression program which was used to obtain the individual station fits. The program was very carefully documented and included specially developed features such as methods for selecting starting values. Ken Rodeman extended Heuser's program in such a manner that it could be used to develop the "Variables Model." Of course the "Constants Model" is a special case of the "Variables Model." The generalization was in no way trivial. It must also be stated that the use of the generalized model is also not trivial, good starting values for all of the regression constants being necessary to assure convergence. Jon Ditmar was responsible for the production of a large part of the results in the report. His devotion to detail and to the accuracy of the results were outstanding. He also made major contributions to documentation of some of the programs and to the careful documentation of the results.

TABLE OF CONTENTS

1.0 INTRODUCTION

Historical records have been kept for World Meteorological Organization stations worldwide for a number of years. Because of their volume, these records have been summarized in various forms to be readily available to a user. One method of summarization, or compaction, is by means of an empirical cumulative distribution function (cdf). The empirical cumulative distribution function is simply the tabulated cumulative relative frequencies, or probabilities that a given climatological variable will fall below specified values. Somerville and Bean (1979) have shown that a number of climatological variables may be modeled with closed form distribution functions. For a given location and time (e.g., month and hour) the historical observations can be used to obtain estimates of the model parameters.

In the present study, we have attempted to model visibility for locations in Germany for which there are no historical records. This has been done by first developing models for stations with existing records, and then attempting to express the parameters of the models as a function of such measured variables as elevation, relative elevation, proximity to water, etc. using regression techniques.

2.0 THE USE OF THE WEIBULL DISTRIBUTION FOR VISIBILITY PROBABILITIES

The Weibull distribution has been found to be useful in modeling visibility by Somerville, Bean and Falls (1979). The probability that visibility is less than x miles, using the Weibull distribution is given by

$$F(x) = 1 - e^{-\alpha x^{\beta}}$$

where α and β are parameters. The values for the parameters α and β vary depending on location, time of day and month. For West Germany, the parameters were estimated by Somerville and Bean (1981) for eight three-hour periods during the day and for each month for 30 locations. The object was to use the estimates of α and β to determine an empirical relationship of the parameters with other measurable variables using regression techniques. The stations used in the study are listed in the Appendix.

3.0 METHODS FOR OBTAINING VISIBILITY MODELS FOR LOCATIONS WITHOUT HISTORICAL RECORDS

There are many variables which may influence visibility. Variables investigated in this study include the following.

1. Elevation.

2. Relative elevation. This is the elevation divided by the "average elevation" of the surrounding area. The "average elevation" is calculated by forming a circle of radius 20 kilometers about the location in question and obtaining the elevations for a grid of values on the circle.

3. East-west elevation difference. This is the difference between the elevation 20 kilometers east and 20 kilometers west of a station.

4. North-south elevation difference. This is the difference between the elevation 20 kilometers north and 20 kilometers south of a station.

5. Proximity to major bodies of water. This is an indicator variable which has the value 1 if the location is near (within 30 kilometers) to an ocean, large river or lake, and has the value 0 otherwise.

6. Population density (individuals per 100 square kilometers).

7. Relative humidity (for a given month and hour period).

8. Mean wind speed (for a given month and hour period).

9. Mean precipitation (by month).

10. Latitude.

11. Longitude.

12. Functions of, and interactions between all of the above.

For a given month and hour period, the values for α and β given in Somerville and Bean (1981) for 30 stations in Germany were regressed on the values for the above variables. That is, each of α and β were modeled as a function of variables thought to be candidates for estimating visibility probabilities. Using these models, values for α and β can be estimated and probabilities for visibilities obtained provided the variables in the regression equations are available.

A stepwise regression program was used to ascertain which of the above variables could be used as predictors for a specified month and hour period. Stepwise regression is a model building procedure which sequentially includes "statistically significant" variables in a model, entering the most important variables first, and removing previously included variables which appear to be redundant given new variables have been included, in an iterative fashion. For a more complete description, the reader is referred to Draper and Smith (1981).

For each month, and for each of the eight 3-hour periods* expressions for each of α and β were obtained which were functions of a selected (by the stepwise regression program) set of the above variables. The regression equations were then re-determined, using the selected variables in a specially designed non-linear regression program, which, using the data from all 30 stations simultaneously, selected the regression coefficients in the expressions for α and β which minimized sum of squares of the differences between the observed and predicted probabilities over all distances and all stations. In non-linear regression, it is necessary to have reasonable "starting values" for the coefficients to be determined, which are then refined by iteration. The "starting values" were the coefficients in the original regression equations for α and β .

The expression which was minimized was

$$\sum_{j=1}^{30} \sum_{i=1}^{14} \left[E_j(x_i) - F_j(x_i;\, \alpha_j, \beta_j) \right]^2 . \tag{3.1}$$

Here x_i is the i^{th} visibility distance included in the RUSSWO's (the 14 distances, in miles, were 1/4, 5/16, 1/2, 5/8, 3/4, 1, 5/4, 3/2, 2, 5/2, 3, 4, 5 and 6). The index j corresponds to the j^{th} station. $E_j(x_i)$ is the empirical probability that the visibility is less than x_i miles for the j^{th} station as obtained from the RUSSWO.

$$F_j(x;\alpha_j,\beta_j) = 1 - e^{-\alpha_j x^{\beta_j}} \tag{3.2}$$

is the model cumulative distribution function (Weibull) for the j^{th} station

*the eight 3-hour periods are 0000-0200, 0300-0500, etc., and are referred to as 3-hour periods 1, 2, 3, ... All times are LST.

where

$$\alpha_j = \gamma_0 + \gamma_1 y_{1j} + \ldots + \gamma_k y_{kj} \tag{3.3}$$

$$\beta_j = \delta_1 + \delta_1 z_{ij} + \ldots + \delta_m z_{mj} \quad . \tag{3.4}$$

The $y_{1j}, y_{2j}, \ldots, y_{kj}$ are the values at the j^{th} station of the k variables selected by the stepwise regression program to obtain α, and z_{ij}, z_{2j}, ... z_{mj} are the values at the j^{th} station of the m variables selected by the stepwise regression program to obtain β. The values $\gamma_0, \gamma_1, \ldots, \gamma_k$ and $\delta_0, \delta_1, \ldots, \delta_m$ are the "improved" regression coefficients for the regressions of α and β on the selected variables.

Exhibit 3.1 illustrates the steps in the model building procedure for a given month and three-hour time period for the "Variables Model."

1. Estimate the parameters α and β for the Weibull model for the individual stations using RUSSWO data

2. Using the stepwise regression program and data for the individual stations, separately regress each of α and β on the candidate variables (topographical, geographic, climatological, etc.) to obtain expressions

$$\hat{\alpha} = \hat{\gamma}_0 + \hat{\gamma}_1 y_1 + \ldots + \hat{\gamma}_k y_k$$

and

$$\hat{\beta} = \hat{\delta}_0 + \hat{\delta}_1 z_1 + \ldots + \hat{\delta}_m z_m$$

where $y_1, y_2, \ldots, y_k$ and $z_1, z_2, \ldots, z_m$ are the variables selected for the regression equations for α and β

3. Using the Weibull model, where

$$F_j(x;\alpha_j,\beta_j) = 1 - e^{-a_j x^{\beta_j}}$$

choose constants $\gamma_0, \gamma_1, \ldots, \gamma_k$ and $\delta_o, \delta_1, \ldots, \delta_m$ so as to minimize

$$\sum_j \sum_i \left[E_j(x_i) - F_j(x_i;\alpha_j,\beta_j) \right]^2$$

where the indices i and j refer to the i^{th} distance and the j^{th} station, and $E_j(x)$ is the empirical cumulative distributive function for j^{th} station.

In the iterative non-linear regression, use the variables selected in Step 2. Initial values for the γ's and δ's are those obtained in Step 2.

Exhibit 3.1

MODEL BUILDING STEPS FOR A SPECIFIED MONTH AND HOUR PERIOD

FOR "VARIABLES MODEL"

4.0 RESULTS

For the 30 German stations used in the study, the values of α and β, for each of the 96 combinations of month and hour period, are given in Somerville and Bean (1981).

For stations for which no historic records are available, but for which values or estimates may be used for such predictor variables as average relative humidity, average windspeed, elevation, etc., Exhibit 4.3 lists the formulas for obtaining values of α and β to be used in the models.

The variables used in the formulas are functions of those given in Exhibit 4.1

ABBREVIATION	ORIGINAL VARIABLE NAME
MP	Mean precipitation in inches for a given month
EL	Location elevation in feet
AE	Average elevation in feet (for locations 20 kilometers distant
NE	Elevation 20 kilometers north of the location
SE	Elevation 20 kilometers south of the location
EE	Elevation 20 kilometers east of the location
WE	Elevation 20 kilometers west of the location
RH	Mean relative humidity for a given month and hour period (values between 0 and 100)
WA	Indicator variable for proximity to water (1 if major water body, 0 otherwise
WN	Mean windspeed for a given month in knots

Exhibit 4.1

ABBREVIATIONS FOR ORIGINAL VARIABLE NAME

SYMBOL USED IN FORMULAS	TRANSFORMATION ON ORIGINAL VARIABLE
RH	$RH^3/10^5$
EL	$EL^3/10^9$
MP	$MP^3/1000$
WN	$WN^3/10$
WA	WA
DN	$(NE-SE)^2/10^5$
DE	$(WE-EE)^2/10^5$
ER	$(EL/AE)^2$

Exhibit 4.2

CODED VARIABLE USED IN FORMULAS

Originally, the stepwise regression program included the variables in Exhibit 4.1 plus their squares, cubes, reciprocals, reciprocals of their squares and two and three way interactions of those terms. Experimentation indicated that in most cases if some power of a variable appeared in a prediction equation, the other powers contributed little. Also, in many cases, one power appeared about as useful as another for prediction purposes (e.g., square vs. cube). Thus on the basis of many runs a suitable power was chosen--or equivalently a variable transformation was made so that the resulting prediction equations would appear more elementary. For example, use of the cube of the value for relative humidity, and the square of the ratio of elevation to average elevation were apparent simplifications. In addition, to be able to limit the range of the values for the coefficients, and to have some commonality of ranges, the variables were coded.

As an example, RH in all of the formulas in Exhibit 4.3 actually refers to 10^{-5} multiplied by the cube of mean relative humidity corresponding to a specific month and hour period. Exhibit 4.1 gives the original variable names and their abbreviations. Exhibit 4.2 gives the meaning of the symbols used in the formulas in Exhibit 4.3.

MONTH	HOUR	DEP VAR	EQUATION
1	1	ALPHA	0.9576D-01 + 0.2134D+01 * EL*MP + 0.5460D-03 * WN*WA
		BETA	0.1264D+01 +-0.8229D-03 * WN*DN
		RMS	0.6221019E-01
1	2	ALPHA	-0.4338D+00 + 0.8456D-01 * RH + 0.2059D-03 * WN*DN
		BETA	0.1169D+01 +-0.2565D-01 * DN*ER
		RMS	0.8146388E-01
1	3	ALPHA	-0.4022D+00 + 0.8441D-01 * RH + 0.5073D-03 * EL*WN
		BETA	0.1106D+01 +-0.2792D-01 * EL*ER + 0.8115D-03 * WN*WA +-0.3203D-03 * WN*DN
		RMS	0.7493435E-01
1	4	ALPHA	0.1753D+00 + 0.5047D-03 * EL*WN + 0.1238D+00 * EL*WA
		BETA	0.1126D+01 +-0.2579D-02 * RH*DN +-0.1292D-02 * EL*WN +-0.6245D-02 * WN*WA
		RMS	0.7366557E-01
1	5	ALPHA	-0.9982D-01 + 0.4000D-01 * RH + 0.1447D-03 * EL*WN + 0.4130D-02 * WN*WA
		BETA	0.1221D+01 +-0.4178D-01 * RH*WA +-0.4630D-02 * EL*DE +-0.5311D-03 * WN*DN
		RMS	0.5516620E-01
1	6	ALPHA	-0.1541D+00 + 0.4895D-01 * RH + 0.3564D-02 * WN*WA
		BETA	0.1202D+01 +-0.3602D-01 * RH*WA +-0.4899D-02 * EL*DE +-0.3125D-03 * WN*DN
		RMS	0.5910714E-01
1	7	ALPHA	0.1380D+00
		BETA	0.1155D+01 + 0.2329D-01 * EL*ER + 0.3113D-02 * WN*WA +-0.2689D-01 * DN*ER
		RMS	0.9058049E-01
1	8	ALPHA	0.8784D-01 + 0.1574D-01 * EL
		BETA	0.1443D+01 +-0.1867D+00 * ER +-0.5468D-03 * WN*DN
		RMS	0.6419713E-01

Exhibit 4.3

EQUATIONS FOR α AND β (VARIABLES MODEL)

```
M
O   H
N   O
T   U   DEP
H   R   VAR    EQUATION
-   -   ---    --------

2   1   ALPHA   0.7495D-01 + 0.1342D-01 * EL*ER +-0.2310D+00 * MP*DE
          + 0.3788D-02 * WA*DE
        BETA    0.1263D+01 +-0.8491D-03 * WN*DN
        RMS     0.5034752E-01
2   2   ALPHA   0.9673D-01 + 0.4517D-03 * EL*WN
        BETA    0.1235D+01 +-0.3058D-01 * DN*ER
        RMS     0.8266603E-01
2   3   ALPHA   0.1183D+00 + 0.2779D-03 * RH*WN
        BETA    0.1047D+01 +-0.4693D-03 * WN*DN
        RMS     0.6698680E-01
2   4   ALPHA   0.1214D+00 + 0.2437D-03 * RH*WN + 0.3464D-01 * WA*ER
        BETA    0.1023D+01
        RMS     0.5699232E-01
2   5   ALPHA   0.5155D-01 + 0.1380D-03 * RH*WN + 0.1340D-01 * RH*WA
          + 0.7519D-04 * WN*DN + 0.1353D-03 * WN*DE
        BETA    0.1351D+01 +-0.6349D-01 * RH*WA +-0.1105D-01 * EL*DE
          +-0.7546D-03 * WN*DN
        RMS     0.3508572E-01
2   6   ALPHA   0.4005D-01 + 0.1432D-03 * RH*WN + 0.1102D-01 * RH*WA
          + 0.4174D-04 * WN*DN + 0.1118D-03 * WN*DE
        BETA    0.1366D+01 +-0.6232D-01 * RH*WA +-0.8889D-02 * EL*DE
          +-0.6608D-03 * WN*DN
        RMS     0.3725996E-01
2   7   ALPHA  -0.8308D-01 + 0.2636D-01 * RH    + 0.2926D-04 * EL*WN
          + 0.1050D-03 * WN*DN + 0.5058D-01 * WA*ER
        BETA    0.1460D+01 +-0.6119D-01 * RH*WA +-0.6454D-02 * RH*DN
          + 0.5811D-02 * RH*ER +-0.6872D-03 * EL*WN
        RMS     0.4414844E-01
2   8   ALPHA   0.3066D-01 + 0.2632D-02 * RH*EL + 0.9326D-04 * RH*WN
          + 0.4852D-02 * WA*DE
        BETA    0.1367D+01 + 0.3819D+00 * EL*MP +-0.7672D-03 * WN*DN
        RMS     0.5248782E-01
```

Exhibit 4.3 (Continued)

```
M
O  H
N  O
T  U  DEP
H  R  VAR    EQUATION
-  -  ---    --------

3  1  ALPHA  0.1667D-01 + 0.1592D+01 * EL*MP
      BETA   0.1440D+01 + 0.1880D+03 * MP*WA
      RMS    0.6469725E-01
3  2  ALPHA  0.4769D-01 + 0.5906D+00 * RH*MP
      BETA   0.1392D+01 +-0.3562D-01 * EL*ER
      RMS    0.6278142E-01
3  3  ALPHA  0.9214D-01 + 0.4253D-01 * EL*WA + 0.3504D+01 * MP*ER
      BETA   0.1191D+01 + 0.3358D-02 * WN    +-0.1263D-02 * EL*WN
       +-0.1325D+00 * EL*WA +-0.6845D-03 * WN*DN
      RMS    0.3995951E-01
3  4  ALPHA  0.7291D-01 + 0.2708D-01 * EL*WA + 0.8620D-03 * EL*DE
      BETA   0.1371D+01 + 0.5447D-02 * RH*WA +-0.1450D-02 * EL*WN
       +-0.3500D-03 * WN*DN + 0.1031D-02 * WN*ER
      RMS    0.3992903E-01
3  5  ALPHA  0.2090D-01 + 0.7870D-03 * RH*EL + 0.5979D-02 * RH*WA
      BETA   0.1634D+01 +-0.2088D-01 * RH*WA +-0.1336D-02 * EL*WN
      RMS    0.3076222E-01
3  6  ALPHA  0.1099D-01 + 0.1384D-02 * RH*EL + 0.3186D-03 * WN*WA
      BETA   0.1758D+01 +-0.6572D-01 * EL*WA +-0.7282D-01 * EL*ER
      RMS    0.2726669E-01
3  7  ALPHA  0.1505D-01 + 0.2928D+00 * EL*MP + 0.3001D-01 * EL*WA
      BETA   0.1716D+01 + 0.8348D-01 * RH*ER +-0.4004D-02 * EL*WN
       +-0.1161D+03 * MP*WA +-0.2367D-01 * DN*ER + 0.3313D-01 * DE*ER
      RMS    0.4043101E-01
3  8  ALPHA  0.1471D-01 +-0.1447D+01 * MP    + 0.1073D+01 * EL*MP
      BETA   0.1947D+01 +-0.2062D-02 * EL*WN +-0.5563D+00 * EL*WA
       +-0.4591D+01 * MP*DN +-0.5208D-01 * WA*DE + 0.8701D+00 * WA*ER
      RMS    0.3373941E-01
```

```
M
O  H
N  O
T  U   DEP
H  R   VAR    EQUATION
-  -   ---    --------

4  1  ALPHA   0.5660D-02 + 0.7667D-03 * RH*EL
      BETA    0.2139D+01 + 0.3879D-02 * DE    +-0.7532D-02 * EL*WN
      RMS     0.3333507E-01
4  2  ALPHA  -0.5035D-01 + 0.1573D-01 * RH
      BETA    0.1496D+01 +-0.2297D-02 * EL*WN + 0.7203D-01 * WA*ER
      RMS     0.5895318E-01
4  3  ALPHA  -0.3018D-01 + 0.1742D-01 * RH
      BETA    0.1791D+01 +-0.8281D-01 * RH    +-0.7389D-03 * EL*WN
       +-0.4864D-03 * WN*DN
      RMS     0.4748061E-01
4  4  ALPHA   0.2253D-01 + 0.1350D-01 * EL*WA + 0.4635D-03 * EL*DE
      BETA    0.1346D+01 + 0.1044D+00 * RH    +-0.1816D-02 * EL*WN
       +-0.4368D-03 * WN*DN
      RMS     0.3049411E-01
4  5  ALPHA   0.6049D-02 + 0.4948D-03 * RH*EL + 0.5224D-02 * EL*WA
      BETA    0.1936D+01 +-0.5773D-01 * EL*ER
      RMS     0.2361841E-01
4  6  ALPHA   0.1773D-02 + 0.3823D-04 * RH*WN +-0.2907D-03 * RH*DN
       + 0.1737D-02 * EL*WA + 0.1926D+00 * MP*ER + 0.5529D-03 * DN*ER
      BETA    0.2003D+01 +-0.6273D-01 * EL*ER
      RMS     0.1719512E-01
4  7  ALPHA   0.1604D-02 + 0.1468D-01 * MP*WN + 0.9804D-03 * DN*ER
      BETA    0.2187D+01 + 0.1305D-01 * RH*WA +-0.2211D+00 * MP*WN
       +-0.3849D-02 * WN*DN
      RMS     0.2852185E-01
4  8  ALPHA   0.5150D-02 + 0.3916D-04 * EL*DN
      BETA    0.2165D+01 +-0.1129D-02 * WN*DN +-0.1289D-02 * WN*DE
      RMS     0.3007792E-01
```

Exhibit 4.3 (Continued)

MONTH	HOUR	DEP VAR	EQUATION
5	1	ALPHA	0.7410D-02
		BETA	0.1897D+01
		RMS	0.3413559E-01
5	2	ALPHA	0.4242D-01
		BETA	0.1324D+01 + 0.2137D-01 * RH*WA
		RMS	0.6455042E-01
5	3	ALPHA	-0.1555D-01 + 0.1065D-01 * RH
		BETA	0.2008D+01 +-0.1032D+00 * RH +-0.7011D-03 * EL*WN +-0.5689D-03 * WN*DN
		RMS	0.4337838E-01
5	4	ALPHA	0.4526D-02 + 0.4496D-04 * EL*WN + 0.1198D-01 * EL*WA
		BETA	0.2302D+01 +-0.6217D-02 * EL*WN +-0.3414D+00 * EL*WA +-0.6407D-03 * WN*DN
		RMS	0.2932565E-01
5	5	ALPHA	0.2198D-02 + 0.3157D-05 * EL*WN
		BETA	0.2138D+01 + 0.1425D-02 * EL*WN +-0.6745D-03 * WN*DN
		RMS	0.1677727E-01
5	6	ALPHA	0.8755D-03 + 0.1895D-06 * EL*DN + 0.2143D-02 * MP*WN
		BETA	0.2318D+01 +-0.1936D+00 * MP*WN
		RMS	0.1065017E-01
5	7	ALPHA	0.6692D-03 +-0.2795D-05 * RH*DN + 0.4627D-04 * EL*DE + 0.2958D-02 * MP*WN + 0.6912D-05 * WN*DN +-0.1055D-03 * WA*DN
		BETA	0.2467D+01 + 0.1518D-01 * EL*WA +-0.2742D+00 * MP*WN +-0.1499D-02 * WN*DN
		RMS	0.1684205E-01
5	8	ALPHA	0.3643D-02
		BETA	0.2204D+01 +-0.2516D-02 * WN*DE
		RMS	0.2685683E-01

Exhibit 4.3 (Continued)

MONTH	HOUR	DEP VAR	EQUATION
6	1	ALPHA	0.6609D-02 + 0.8787D-04 * ER
		BETA	0.2009D+01 + 0.4419D+00 * MP*DE
		RMS	0.3904460E-01
6	2	ALPHA	0.5063D-01
		BETA	0.1277D+01 +-0.3837D-03 * EL*WN
		RMS	0.6901203E-01
6	3	ALPHA	0.3968D-01 + 0.2098D-01 * EL*WA
		BETA	0.9848D+00 + 0.8233D-01 * RH +-0.6223D-03 * WN*DN
		RMS	0.4973479E-01
6	4	ALPHA	0.2354D-02 +-0.3327D-03 * WN + 0.1962D-03 * RH*WN + 0.2578D+00 * MP*WA + 0.7769D-04 * DN*ER
		BETA	0.2085D+01 +-0.4359D-01 * RH*ER
		RMS	0.2040592E-01
6	5	ALPHA	0.9124D-03 +-0.1055D-03 * WN + 0.8177D-04 * RH*WN + 0.6520D-01 * MP*WA
		BETA	0.2381D+01 +-0.6358D-01 * RH*ER
		RMS	0.1250483E-01
6	6	ALPHA	-0.1168D-02 + 0.1424D-02 * RH +-0.5697D-04 * DN + 0.3356D-05 * WN*DN + 0.3285D-04 * WA*DN
		BETA	0.2312D+01 + 0.4820D-02 * RH*ER
		RMS	0.1265939E-01
6	7	ALPHA	0.1266D-02 +-0.8088D-04 * DN + 0.6170D-04 * EL*WN + 0.3075D-05 * WN*DN
		BETA	0.2252D+01 +-0.4157D-02 * EL*WN
		RMS	0.2325618E-01
6	8	ALPHA	0.2181D-02 + 0.5708D-04 * RH*EL + 0.4724D-04 * EL*WN
		BETA	0.2325D+01 +-0.5185D-02 * EL*WN
		RMS	0.2444602E-01

Exhibit 4.3 (Continued)

MONTH	HOUR	DEP VAR	EQUATION
7	1	ALPHA	0.6896D-02
		BETA	0.1974D+01
		RMS	0.4642356E-01
7	2	ALPHA	-0.4532D-01 + 0.1288D-01 * RH
		BETA	0.1387D+01
		RMS	0.7033592E-01
7	3	ALPHA	-0.1741D-01 + 0.9946D-02 * RH + 0.1487D-01 * EL*WA
		BETA	0.1656D+01 +-0.3646D-01 * RH
		RMS	0.4588298E-01
7	4	ALPHA	0.8832D-03 + 0.1064D-03 * RH*WN
		BETA	0.2536D+01 +-0.7980D-02 * RH*WN
		RMS	0.2934230E-01
7	5	ALPHA	0.9843D-03 +-0.5708D-04 * WN + 0.5376D-04 * RH*WN
		BETA	0.2357D+01 + 0.2834D+00 * WA +-0.7785D-01 * RH*ER
		RMS	0.1290813E-01
7	6	ALPHA	0.1663D-02 +-0.6203D-03 * EL*MP + 0.1414D-04 * EL*WN +-0.2829D-03 * EL*ER + 0.1416D-02 * MP*WN
		BETA	0.1934D+01 + 0.2504D-02 * EL*WN
		RMS	0.8789920E-02
7	7	ALPHA	0.1109D-02 +-0.3420D-03 * WN + 0.1894D-03 * RH*WN
		BETA	0.1984D+01 +-0.1102D-02 * EL*WN
		RMS	0.1794515E-01
7	8	ALPHA	0.1724D-02
		BETA	0.2526D+01
		RMS	0.3249431E-01

Exhibit 4.3 (Continued)

MONTH	HOUR	DEP VAR	EQUATION
8	1	ALPHA	0.1251D-01 + 0.4020D-04 * EL*DN
		BETA	0.1994D+01 +-0.2401D-01 * WN
		RMS	0.3468117E-01
8	2	ALPHA	-0.7094D-01 + 0.2076D-01 * RH +-0.3889D+00 * MP*WA
		BETA	0.1384D+01 +-0.3036D-01 * RH +-0.3877D-02 * DN*ER
		RMS	0.6515279E-01
8	3	ALPHA	-0.6833D-01 + 0.2495D-01 * RH + 0.5541D-01 * EL*WA +-0.3592D+00 * MP*WA
		BETA	0.1737D+01 +-0.1008D+00 * RH + 0.3541D-01 * ER +-0.9965D-03 * WN*DN
		RMS	0.5611358E-01
8	4	ALPHA	-0.1018D-01 + 0.7519D-02 * RH + 0.1407D-01 * EL*WA
		BETA	0.2358D+01 +-0.1777D+00 * RH
		RMS	0.3283286E-01
8	5	ALPHA	0.1266D-02 + 0.7862D-03 * RH*ER
		BETA	0.2453D+01 +-0.9910D-01 * RH*ER
		RMS	0.2011605E-01
8	6	ALPHA	0.9766D-03 + 0.4392D-03 * RH*ER
		BETA	0.2283D+01
		RMS	0.1480237E-01
8	7	ALPHA	0.2553D-02 +-0.1417D-03 * DN + 0.1443D-03 * DN*ER
		BETA	0.2245D+01
		RMS	0.2197240E-01
8	8	ALPHA	0.6065D-01 +-0.9221D-02 * RH + 0.1208D-02 * EL*DE
		BETA	0.1107D+01
		RMS	0.6445315E-01

Exhibit 4.3 (Continued)

MONTH	HOUR	DEP VAR	EQUATION
9	1	ALPHA	-0.4024D-02 + 0.7689D-02 * RH
		BETA	0.1440D+01 +-0.3526D-01 * RH*ER
		RMS	0.6334446E-01
9	2	ALPHA	-0.4043D+00 + 0.7685D-01 * RH
		BETA	0.1914D+01 +-0.1188D+00 * RH +-0.1925D+00 * ER
		RMS	0.7961287E-01
9	3	ALPHA	-0.5335D+00 + 0.1080D+00 * RH +-0.2708D+00 * EL*MP
		BETA	0.2018D+01 +-0.1735D+00 * RH + 0.1228D-01 * ER
		RMS	0.5935084E-01
9	4	ALPHA	-0.6192D-01 + 0.2734D-01 * RH + 0.3096D-02 * WN*WA
		BETA	0.1729D+01 +-0.1149D+00 * RH
		RMS	0.4147219E-01
9	5	ALPHA	0.4858D-02 + 0.2807D-01 * MP*WN + 0.1186D-02 * WN*WA
		BETA	0.1904D+01 +-0.1938D-01 * WN*WA +-0.1125D-02 * WN*DN
		RMS	0.2505645E-01
9	6	ALPHA	0.4007D-02 + 0.1064D-01 * MP*WN + 0.9421D-03 * WA*DN
		BETA	0.1916D+01
		RMS	0.1763006E-01
9	7	ALPHA	0.4679D-02 + 0.3503D-01 * MP*WN
		BETA	0.1886D+01
		RMS	0.2593861E-01
9	8	ALPHA	0.1012D-01
		BETA	0.2235D+01 +-0.1563D-01 * WN +-0.1076D-02 * RH*WN
		RMS	0.4092572E-01

Exhibit 4.3 (Continued)

```
M
O  H
N  O
T  U   DEP
H  R   VAR    EQUATION
-  -   ---    --------

10  1  ALPHA  0.1329D+00
       BETA   0.9259D+00
       RMS    0.6887226E-01

10  2  ALPHA -0.3569D+00 + 0.7974D-01 * RH
       BETA   0.7334D+00
       RMS    0.9098264E-01

10  3  ALPHA -0.1627D+00 + 0.6605D-01 * RH    +-0.4261D+00 * RH*MP
        + 0.1415D+00 * EL*WA + 0.3360D-02 * EL*DE
       BETA   0.6745D+00 +-0.2178D+00 * EL*WA
       RMS    0.4880673E-01

10  4  ALPHA -0.2783D+00 + 0.7642D-01 * RH    + 0.1752D-01 * RH*WA
        + 0.8163D-03 * WN*ER
       BETA   0.2344D+01 +-0.2399D+00 * RH    +-0.2517D-01 * RH*WA
        +-0.1888D-02 * EL*WN +-0.5659D-02 * DN*DE
       RMS    0.3688562E-01

10  5  ALPHA  0.1793D-02 + 0.7048D-02 * RH    + 0.1621D-03 * RH*WN
        + 0.1841D-01 * RH*WA
       BETA   0.1503D+01 +-0.1060D-02 * RH*WN +-0.9405D-01 * RH*WA
        +-0.1006D-01 * DN*ER
       RMS    0.3120006E-01

10  6  ALPHA -0.2895D-01 + 0.1450D-01 * RH    + 0.1383D-01 * RH*WA
       BETA   0.1917D+01 +-0.8225D-01 * RH    +-0.1228D+00 * RH*WA
        +-0.5562D+00 * MP*WN
       RMS    0.3312006E-01

10  7  ALPHA  0.5811D-02 + 0.1121D-01 * RH
       BETA  -0.1842D+00 + 0.2488D+00 * RH    + 0.4138D-01 * RH*WA
        + 0.1124D+00 * MP*WN +-0.2861D+01 * MP*DE
       RMS    0.7974254E-01

10  8  ALPHA  0.6371D-01
       BETA   0.1230D+01
       RMS    0.6072881E-01
```

Exhibit 4.3 (Continued)

```
M
O   H
N   O
T   U   DEP
H   R   VAR    EQUATION
-   -   ---    --------

11  1   ALPHA -0.8053D-01 + 0.2526D-01 * RH    +-0.6530D-03 * WN
         + 0.7042D+00 * RH*NP

        BETA   0.1340D+01 +-0.2162D+02 * MP    +-0.7705D-02 * RH*EL

        RMS    0.4733886E-01

11  2   ALPHA -0.4243D+00 + 0.7751D-01 * RH    + 0.2380D+01 * MP*ER

        BETA   0.1120D+01 +-0.2806D-02 * EL*WN +-0.2221D+00 * MP*DN

        RMS    0.6163124E-01

11  3   ALPHA  0.1622D+00 + 0.6130D-01 * EL*WA + 0.1904D+01 * MP*ER

        BETA   0.9815D+00 +-0.4654D-03 * EL*WN +-0.1056D+01 * MP*DN
         +-0.3017D-02 * WN*WA

        RMS    0.5082504E-01

11  4   ALPHA -0.2508D+00 + 0.6206D-01 * RH    + 0.7598D-01 * WA
         + 0.1353D+01 * MP*ER

        BETA   0.2213D+01 +-0.1841D+00 * RH    +-0.1645D+00 * WA
         +-0.8259D-03 * EL*WN +-0.6887D+00 * MP*DN

        RMS    0.4053295E-01

11  5   ALPHA  0.8113D-01 + 0.2214D-01 * MP*WN + 0.2531D-02 * WN*WA

        BETA   0.1214D+01 +-0.1229D-01 * RH    +-0.6608D-01 * WA
         +-0.6428D-03 * EL*WN +-0.5605D+00 * MP*DN

        RMS    0.3738825E-01

11  6   ALPHA  0.6670D-01 + 0.2634D-03 * EL*WN + 0.1724D+00 * MP*DE
         + 0.3059D-02 * WN*WA

        BETA   0.1206D+01 +-0.2950D-01 * RH*WA +-0.2325D-02 * EL*WN
         + 0.3435D-03 * WN*ER

        RMS    0.3872498E-01

11  7   ALPHA -0.2453D+00 + 0.5249D-01 * RH    + 0.9799D+00 * MP*ER
         + 0.1522D-02 * WN*WA

        BETA   0.1203D+01 +-0.4147D-01 * EL*ER

        RMS    0.5391571E-01

11  8   ALPHA  0.1058D+00

        BETA   0.1136D+01 +-0.1568D-02 * EL*WN

        RMS    0.5641866E-01
```

Exhibit 4.3 (Continued)

MONTH	HOUR	DEP VAR	EQUATION
12	1	ALPHA	0.1087D+00 + 0.4124D-01 * EL +-0.1923D+00 * RH*MP
		BETA	0.1125D+01 +-0.6103D-01 * EL*ER + 0.1531D+01 * MP*DE
		RMS	0.5875115E-01
12	2	ALPHA	0.1518D+00 + 0.4977D-03 * EL*WN +-0.2448D-02 * EL*DE
		BETA	0.1063D+01 +-0.1822D-01 * DN*ER
		RMS	0.6859881E-01
12	3	ALPHA	0.1383D+00 + 0.2463D-03 * EL*WN + 0.2253D-03 * WN*DN
		BETA	0.1131D+01 +-0.3462D-01 * DN*ER
		RMS	0.4941199E-01
12	4	ALPHA	0.1625D+00 + 0.2564D-03 * WN*DN
		BETA	0.1110D+01 +-0.3083D-01 * DN*ER
		RMS	0.4839368E-01
12	5	ALPHA	0.1119D+00 + 0.1434D-02 * WN*WA + 0.2193D-03 * WN*DN
		BETA	0.1181D+01 +-0.1049D-02 * WN*DN
		RMS	0.4628299E-01
12	6	ALPHA	0.1072D+00 + 0.1387D-03 * EL*WN + 0.2863D+00 * EL*WA + 0.1984D-03 * WN*DN
		BETA	0.1203D+01 +-0.8617D+00 * EL*WA +-0.3015D-01 * DN*ER
		RMS	0.4266235E-01
12	7	ALPHA	0.1083D+00 + 0.4757D-03 * RH*DN + 0.3151D-03 * EL*WN
		BETA	0.1209D+01 +-0.2966D-01 * DN*ER
		RMS	0.5020483E-01
12	8	ALPHA	0.1097D+00 + 0.1642D-01 * EL*ER
		BETA	0.1170D+01 +-0.7912D-03 * WN*DN
		RMS	0.7029019E-01

Exhibit 4.3 (Continued)

VARIABLES USED IN ALPHA EQUATIONS:

MONTH HOUR VARIABLE INDEX

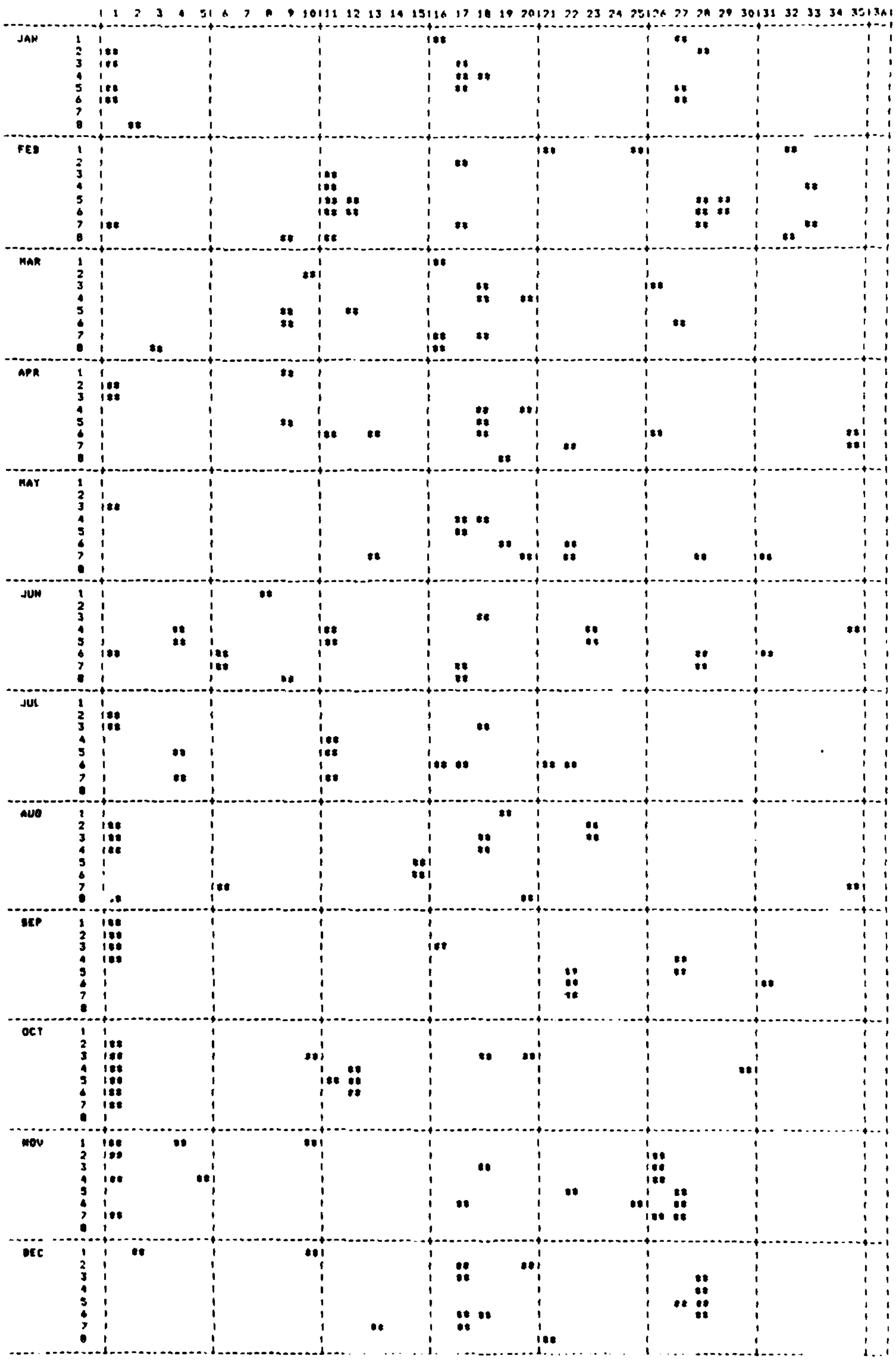

Exhibit 4.4

VARIABLES USED IN BETA EQUATIONS:

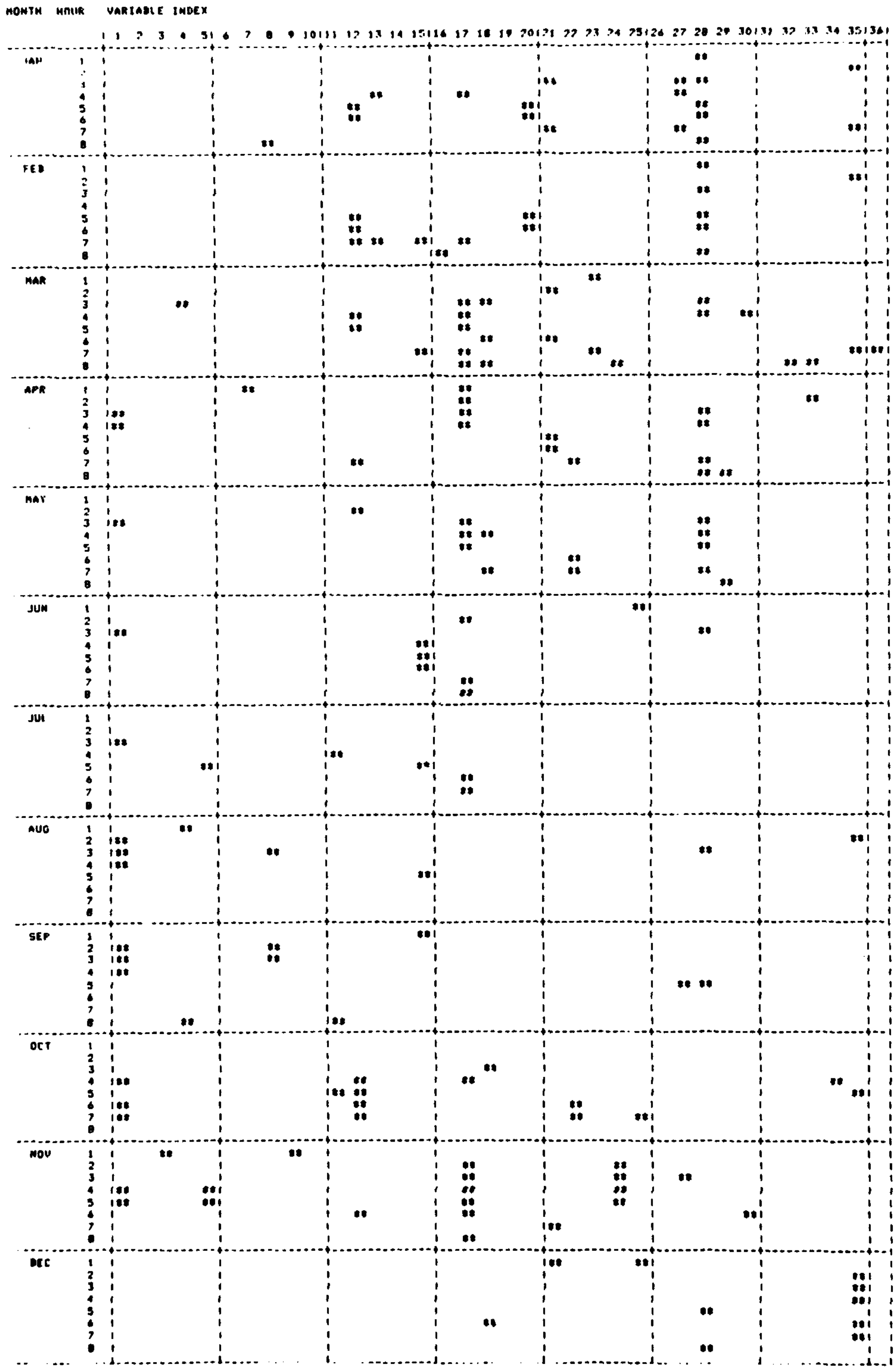

Exhibit 4.5

Exhibits 4.4 and 4.5 indicate the month and hour period for which the single factor or interaction terms are used in the prediction equations for α and β respectively. In Exhibits 4.4 and 4.5 the variables are referred to by index numbers 1 to 36 for economies of space. Exhibit 4.6 gives the coded terms corresponding to these index numbers.

1	RH	10	RH x MP	19	EL x DN	28	WN x DN
2	EL	11	RH x WN	20	EL x DE	29	WN x DE
3	MP	12	RH x WA	21	EL x ER	30	WN x ER
4	WN	13	RH x DN	22	MP x WN	31	WA x DN
5	WA	14	RH x DE	23	MP x WA	32	WA x DE
6	DN	15	RH x ER	24	MP x DN	33	WA x ER
7	DE	16	EL x MP	25	MP x DE	34	DN x DE
8	ER	17	EL x WN	26	MP x ER	35	DN x ER
9	RH x EL	18	EL x WA	27	WN x WA	36	DE x ER

Exhibit 4.6

TERMS CORRESPONDING TO INDEX VARIABLES IN EXHIBITS 4.4 AND 4.5

		VARIABLE							
		RH	EL	MP	WN	WA	DN	DE	ER
α	Main Effect Only	29	1	1	4	1	3	0	1
	All Terms	64	55	32	62	43	29	10	19
β	Main Effect Only	16	0	1	3	3	0	1	4
	All Terms	44	47	17	71	34	44	13	36

Exhibit 4.7

FREQUENCY OF APPEARANCE OF VARIABLES IN EXPRESSIONS FOR

ALPHA AND BETA ("VARIABLES MODEL")

Exhibit 4.7 gives the frequency of appearance of variables in expressions for α and β. It is worth remarking that relative humidity appears more often in expressions for predicting α and β than any other variable used, and as a "main effect" term it appears in 29 of the 96 expressions for α and 16 of the 96 expressions for β. Elevation and wind also appear in many of the equations, but almost always as "interaction" terms. This suggests that humidity by itself is useful in obtaining expressions for α and β, but elevation and wind are useful only in combination with other variables.

Interaction terms which appear frequently in expressions for α are EL x WN and EL x WA, each of which occur in 15 of the expressions. Those which appear frequently in expressions for β are EL x WN, WN x DN, EL x WA, RH x WA, RH x WN, WN x WA, and DN x ER which occur 41, 36, 22, 20, 15, 15 and 15 times respectively. The interaction terms WN x DN and WN x EL occur most frequently in the expressions for β for the Winter and Spring months.

There are situations where no knowledge of observable climatological, geographical or other variables is known (or we wish to ignore it in the interest of simplicity). For these cases, we have developed constants models for the entire region of West Germany using the Weibull distribution, which have fixed values for α and β for each of the 96 combinations of month and three-hour period. Exhibit 4.8 gives values for the constants and also RMS values over all stations and distances. These values were obtained by the same method as for the previous models.

HOUR PERIOD

MONTH		1	2	3	4	5	6	7	8	ALL HOURS
	α	.111	.50	.192	.213	.144	.130	.137	.108	
JAN	β	1.23	1.13	1.05	1.02	1.12	1.14	1.17	1.27	
	RMS	.068	.102	.107	.099	.087	.078	.091	.075	.089
		.098	.117	.164	.160	.089	.070	.077	.076	
FEB		1.22	1.19	1.04	1.06	1.23	1.27	1.27	1.32	
		.082	.093	.078	.064	.057	.053	.072	.090	.075
		.026	.066	.116	.078	.031	.019	.022	.015	
MAR		1.66	1.34	1.17	1.32	1.55	1.68	1.68	1.89	
		.048	.086	.066	.057	.053	.041	.051	.055	.059
		.013	.042	.063	.024	.0071	.0040	.0055	.0051	
APR		1.75	1.39	1.30	1.61	1.92	2.08	1.98	2.08	
		.047	.073	.054	.042	.029	.027	.042	.034	.046
		.0071	.039	.039	.0069	.0016	.0012	.0017	.0030	
MAY		1.94	1.38	1.43	2.04	2.43	2.41	2.35	2.24	
		.034	.064	.045	.029	.016	.013	.021	.028	.035
		.0086	.048	.038	.0068	.0017	.0011	.0021	.0041	
JUNE		1.94	1.29	1.45	2.04	2.44	2.51	2.27	2.12	
		.053	.067	.052	.035	.019	.016	.026	.027	.041
		.0070	.037	.035	.0051	.0014	.0012	.0018	.0017	
JULY		1.99	1.43	1.52	2.20	2.41	2.31	2.24	2.53	
		.045	.074	.052	.031	.016	.012	.026	.031	.041
		.012	.059	.081	.016	.0029	.0014	.0021	.0092	
AUG		1.75	1.23	1.17	1.76	2.26	2.39	2.32	1.71	
		.040	.076	.076	.047	.025	.015	.023	.071	.052
		.044	.150	.200	.058	.010	.0042	.0077	.010	
SEPT		1.29	.889	.832	1.30	1.87	2.10	1.95	2.00	
		.066	.101	.088	.062	.049	.025	.049	.046	.065
		.126	.231	.322	.179	.050	.031	.055	.063	
OCT		.981	.777	.678	.899	1.33	1.49	1.33	1.27	
		.068	.100	.080	.075	.059	.049	.087	.061	.074
		.119	.155	.182	.162	.093	.089	.101	.103	
NOV		1.07	.978	.927	.970	1.13	1.11	1.13	1.11	
		.062	.091	.070	.066	.059	.063	.087	.061	.071
		.146	.168	.173	.192	.138	.136	.140	.144	
DEC		1.08	1.04	1.04	1.02	1.10	1.10	1.12	1.12	
		.083	.094	.082	.078	.075	.076	.075	.105	.084
ALL MONTHS		.060	.086	.073	.061	.051	.046	.060	.062	.063

Exhibit 4.8

VALUES OF α, β AND RMS FOR "CONSTANT MODEL"

The expression minimized was (3.1) of section 3.0, with expressions (3.3) and (3.4) containing only the constant terms γ_0 and δ_0 respectively. In other words, the best (α,β) combination for the entire region is found by minimizing

$$\sum_{j=1}^{30} \sum_{i=1}^{14} \left[E_j(x_i) - F(x_i;\alpha,\beta)\right]^2 \tag{4.1}$$

with respect to α and β. $E_j(x_i)$ is the empirical probability of less than x_i miles of visibility at station j. $F(x_i;\alpha,\beta)$ is the Weibull model for visibility. Note that in this case we consider (α,β) as constants for the entire region of West Germany. That is, we obtain a single regional probability model for a given month and hour period.

For example, for February for the third hour period we have the regional model given by

$$F(x) = 1 - e^{-.164x^{1.04}} \tag{4.2}$$

This regional model can be used for the entire West German region for February third hour period and yields an overall RMS of .078.

5.0 ACCURACY OF THE RESULTS

Exhibit 5.1 gives a comparison of the accuracies of the two models. The values given are the RMS values of the differences between the model predicted probabilities and the observed probabilities (RUSSWO values) over all distances and over all of the thirty stations.

	HOUR (LST)								
	0100	0400	0700	1000	1300	1600	1900	2000	Overall
JAN.	.062 .068	.081 .102	.075 .107	.074 .099	.055 .087	.059 .078	.091 .091	.064 .075	.071 .088
FEB.	.050 .082	.083 .093	.067 .078	.057 .064	.035 .057	.037 .053	.044 .072	.052 .090	.048 .074
MAR.	.065 .048	.063 .086	.040 .066	.040 .057	.031 .053	.027 .041	.040 .051	.034 .055	.043 .057
APR.	.033 .047	.059 .073	.047 .054	.030 .042	.024 .029	.017 .027	.029 .042	.030 .034	.034 .043
MAY	.034 .034	.065 .064	.043 .045	.029 .029	.017 .016	.011 .013	.017 .021	.027 .028	.030 .035
JUNE	.039 .053	.069 .067	.050 .052	.020 .035	.013 .019	.013 .016	.023 .026	.024 .027	.031 .041
JULY	.046 .045	.070 .074	.046 .052	.029 .031	.013 .016	.009 .012	.018 .026	.032 .031	.033 .041
AUG.	.035 .040	.065 .076	.056 .076	.033 .047	.020 .025	.015 .015	.022 .023	.064 .071	.039 .052
SEPT.	.063 .066	.080 .101	.059 .088	.041 .062	.025 .049	.018 .025	.026 .049	.041 .046	.044 .061
OCT.	.069 .068	.091 .100	.049 .080	.037 .075	.031 .059	.033 .049	.080 .087	.061 .061	.056 .072
NOV.	.047 .062	.062 .091	.051 .070	.041 .066	.037 .059	.039 .063	.054 .087	.056 .061	.048 .070
DEC.	.059 .083	.069 .094	.049 .082	.048 .078	.046 .075	.043 .076	.050 .075	.070 .105	.054 .084
Overall	.048 .060	.071 .086	.053 .073	.040 .061	.029 .051	.027 .046	.041 .060	.046 .062	.044 .063

Exhibit 5.1

RMS VALUES FOR THE "VARIABLES MODEL" AND THE "CONSTANTS MODEL"
(The bottom figure for each pair is for the Constants Model)

It is worth noting that the RMS values are lowest for the month of May and for hour period 6 (1500-1700 hours). The RMS values are highest for January and for hour period 2 (0300-0500 hours). This may be because visibilities are worst for these times, or for the case of hour period 2, that the observations are less accurate.

There are some apparent anomolies in Exhibit 5.1. For March, and the first three hour period, the RMS value for the Variables Model is larger than the RMS value for the Constants Model. The explanation is that in the development of the Variables Model, for a specific hour period some of the stations had to be omitted because values of a climatological variable were not available for that station. For the period 0000-0200 hours for March, the stepwise procedure called for mean monthly windspeed and mean monthly precipitation. For two of the 21 stations with RUSSWO data, the latter was not available and for another the former could not be obtained. These stations were ones for which the Constants Model gave better than average fits.

Exhibit 5.2 compares the RMS for the 30 German stations for January 1000 hours for the Constants Model, the Variables Model and the individual station models. The overall RMS values for the three models are .099, .074, and .031. Again RMS values are not given for the variables model for a number of stations because values for the variables called for by the stepwise regression model were not available. Availability of these values would be expected to improve the RMS value of .074. It may be noted that the RUSSWO periods of observation for Baumholder and Siegenberg are 6 years and 3 years respectively, which may account, at least partially for their large RMS values.

STATION	CONSTANTS MODEL	VARIABLES MODEL	INDIVIDUAL STATION MODELS
	RMS VALUES		
Hahn	.099	.060	.013
Bitburg	.052	.046	.014
Ramstein	.107	.090	.012
Spangdahlem	.061	.045	.011
Tempelhof	.078	.078	.030
Ansbach	.028	.026	.022
Fulda	.026	.021	.020
Erding	.082	.076	.009
Feucht	.041	.047	.021
Baumholder	.209	.215	.051
Bad Kreuznach	.023	---	.012
Bad Tolz	.171	.132	.032
Zweibrucken	.040	.034	.017
Wiesbaden	.022	.046	.010
Finthen	.051	.036	.011
Furth	.133	---	.048
Hanau	.035	---	.025
Gablingen	.053	.062	.033
Giebelstadt	.066	.051	.014
Grafenwohr	.077	.085	.022
Heidelberg	.045	.020	.012
Illeshein	.086	---	.016
Kitzingen	.060	.032	.009
Nurnberg	.071	---	.020
Coleman	.069	---	.016
Wertheim	.121	.046	.016
Schwaebisch Hall	.082	.067	.033
Sembach	.026	.025	.013
Siegenberg	.296	---	.116
Echterdingen	.072	.059	.021
Overall	.099	.074	.031

Exhibit 5.2

RMS OF FITS FOR WEST GERMAN STATIONS

January 1000 Hours

It is worth noting that the RMS values are differences between the model estimates of the probabilities of visibility and those of the observations from the RUSSWO data. The latter are based on the observers subjective classification which contribute to an inherent error which in turn contributes to the increased size of all RMS's. It is indeed quite possible that estimates from some of the models (for example those of the individual stations) might be an improvement over the corresponding RUSSWO estimates.

6.0 USING THE VISIBILITY MODELS

Example 1 It is desired to obtain the probability of visibility less than 4 miles at a location where there are no historical records for visibility. The probability is needed for November at approximately 0700 hours. We are willing to estimate the following for the location (it is not near a major body of water).

November mean precipitation in inches	1.5
Elevation in feet	1000
Mean relative humidity (per cent) for 0700 hours in November	80
North-South elevation differential (feet)	-500
East-West elevation differential (feet)	100
Mean November windspeed (knots)	4
Relative elevation (elevation/average elevation)	1.1

From Exhibit 4.3, we estimate α and β for the problem using

$$\alpha = .1622 + .0613 \text{ EL*WA} + 1.904 \text{ MP*ER}$$

$$\beta = .9815 - .0004654 \text{ EL*WN} - 1.056 \text{ MP*DN} - .003017 \text{ WN*WA}$$

Using Exhibit 4.2,

$EL = 1000^3/10^9 \quad = 1$

$WA \quad = 0$

$MP = 1.5^3/1000 \quad = .003375$

$ER = 1.1^2 \quad = 1.21$

$WN = 4^3/10 \quad = 6.4$

$DN = (-500)^2/10^2 \quad = 2.5$

Calculating, we have $\alpha = .1700$

$\beta = .9696$

Using the Weibull model,

$$\text{Prob [Visibility} < 4 \text{]} = 1 - e^{-.1700(4)^{.9696}} = .48 \quad .$$

The probability of visibility less than 4 miles is estimated as .48.

Example 2 We wish to find the probability of visibility less than 1 mile in March at 1000 hours for a specified location. There are no historical records for visibility. We choose not to use estimates for geographic or climatic variables. Using Exhibit 4.8 we find that for March and the fourth 3-hour period, the values for α and β can be taken as .078 and 1.32 respectively. The probability of visibility less than or equal to x miles is given as

$$1 - e^{-.078x^{1.32}}$$

The probability that visibility is less than 1 mile is estimated to be .075.

7.0 ADDITIONAL COMMENTS

In the present report the RMS values (estimates of error for calculated probabilities) are internal estimates. A better estimate of error could be obtained using data from a set of stations not used in determining the prediction equations. Future work includes use of a new set of data from several stations in West Germany to evaluate the capability of the model for these stations.

In addition, we plan to utilize sample re-use techniques such as those described by Geisser (1975).

It will be necessary to develop models using data from other regions. It is possible that a small set of models might be sufficient for a major portion of the globe. The present work should be extended to other weather elements such as ceiling, windspeed and precipitation.

8.0 REFERENCES

1. Draper, N.R. and H. Smith, 1981: Applied Regression Analysis, John Wiley and Sons, N.Y.

2. Geisser, Seymour, 1975: The predictive Sample Reuse Method With Applications, Journal of the American Statistical Association pp. 320-328.

3. Heuser, Mark, Paul N. Somerville and Steven J. Bean, 1980: Least Squares Fitting of Distributions Using Non-linear Regression, AFGL-TR-80-0362.

4. Somerville, Paul N. and Steven J. Bean, 1979: Statistical Modeling of Climatic Probabilities. AFGL-TR-79-0222.

5. Somerville, Paul N., Steven J. Bean and Sherrill Falls, 1979: Some Models for Visibility. AFGL-TR-79-0144.

6. Somerville, P.N. and S. J. Bean, 1981: Some Models for Visibility for German Stations. AFGL-TR-81-0144.

APPENDIX

STATIONS USED IN THE STUDY

NO.	STATION	WBAN	LAT.	LONG.	ELEV. (FEET)
1	Hahn AB	34055	49.95	7.27	1650
2	Bitburg AB	34049	49.95	6.57	1228
3	Ramstein AB	34050	49.43	7.58	780
4	Spangdahlem AB	34054	49.97	6.70	1196
5	Tempelhof APRT	35104	52.47	13.40	164
6	Ansbach AAF	34172	49.32	10.63	1542
7	Fulda AAF	35053	50.53	9.63	1010
8	Erding AS	34168	48.32	11.93	1522
9	Feucht AAF	34198	49.38	11.18	1265
10	Baumholder AAF	34077	49.65	7.30	1408
11	Bad Kreuznach AAF	34070	49.87	7.88	355
12	Bad Tolz AAF	34197	47.77	11.60	2360
13	Zweibrucken AB	34058	49.22	7.40	1132
14	Wiesbaden AB	35010	50.05	8.33	470
15	Finthen AAF	34075	49.97	8.15	769
16	Furth AAF	34176	49.50	10.93	1000
17	Hanau AAF	35009	50.17	8.95	377
18	Gablingen AAF	34196	48.45	10.87	1530
19	Giebelstadt AUX AF	34036	49.67	9.88	985
20	Grafenwohr AAF	34189	49.70	11.95	1370
21	Heidelberg AAF	34046	49.40	8.65	369
22	Illesheim AAF	34190	49.47	10.38	1060
23	Kitzinger AAF	34191	49.75	10.20	699
24	Nurnberg	34177	49.50	11.08	1053
25	Coleman AAF	34068	49.57	8.47	334
26	Wertheim AAF	34076	49.77	9.48	1120
27	Schwaebisch Hall AAF	34074	49.17	9.78	1303
28	Sembach AB	34056	49.52	7.87	1052
29	Siegenberg Gunnery Range	34199	48.75	11.80	1325
30	Echterdingen ARPT	34041	48.68	9.22	1306